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# Building An FM Crystal Receiver!

Our earlier crystal receiver projects proved popular, so here's another crystal receiver with an odd twist: it's intended to intercept stations on the 88- to 108-MHz FM band! With some modification, it'll also copy nearby VHF AM aviation band traffic, just the ticket for eavesdropping while watching the activity at your local airfield! FM crystal receiver projects aren't new; this project is based on material from an article that ran back in the 1950s, but with some modern refinements to improve performance. Most of the parts you'll need to build this project can be found in your junkbox, but I'll also provide some mail-order sources for those of you who don't have goodies hoarded away!

Monitoring FM signals is more challenging than tuning in your local AM stations with a simple crystal set. There are two reasons: AM signals are readily detected by a crystal-diode detector, and a simple longwire antenna will usually suffice in providing enough signal level so you can hear at least a few of the local stations. FM is a different animal. A crystal detector recovers both a DC and audio signal from an AM carrier, a simple diode detector will only produce a DC signal component when monitoring a FM signal. Since there are no AM sidebands to mix with the carrier in the detector, none of the audible information is recovered.

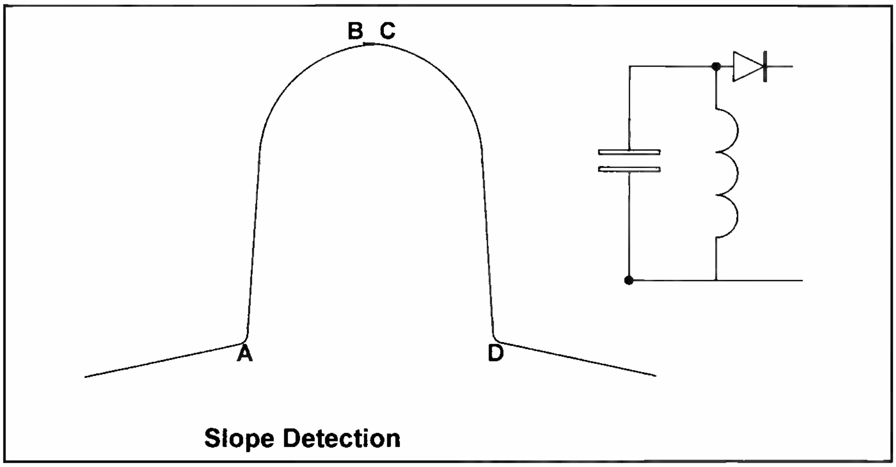


*Figure 1. Here's a representative tuning curve for an LC tuned circuit as found in our FM Crystal Set. Slope detection occurs when the FM carrier straddles either side of the tuning curve between points A and B or C and D. An AM carrier would be centered between points B and C for best AM detection.*

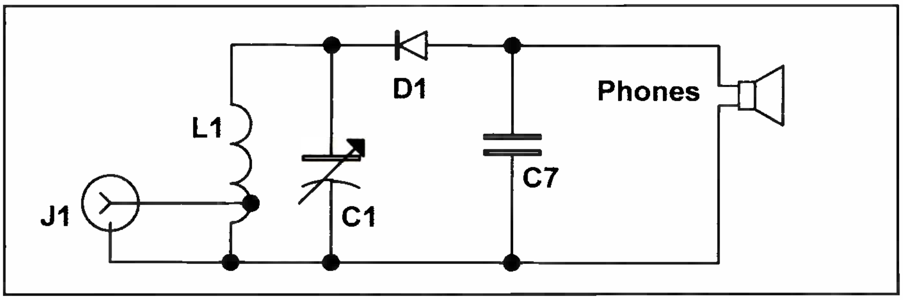


*Figure 2. Here's the schematic for the simple and basic FM crystal receiver. FM performance is about 20 dB down from AM signals in the same tuning range. It makes a good companion at the local airfield to monitor AM aircraft and tower traffic in the 120-MHz region.*

## Slope Detection

So, how's it possible to make a working FM crystal radio? Good question. The answer lies in using a technique called "Slope Detection." FM is simply a carrier being shifted in frequency at an audible rate. The rate of shift corresponds to the frequency of the audio signal while the excursion, or carrier deviation, represents the audio signal level, or amplitude. U.S. FM broadcasters are allowed a deviation of ± 75 kHz, or 150 kHz total. This means we can hear FM signals on a simple crystal radio, providing the tuned circuit has enough Q for the recovered audio to be great enough to drive a pair of headphones. Whereas a crystal detector will detect AM signals without tuned circuits, the FM set relies on a very sharply tuned high-Q circuit to work. If we tune the FM station so it falls on either side of the slope, the modulated FM carrier will be converted to AM since its signal amplitude will vary depending on where it falls on the tuning slope at any given instant.

Many early 2-meter amateur FM repeater operators used AM transceivers, modified with simple external FM modulators, while using slope detection to hear the FM repeaters. Most of these early AM receivers were 15 or 30 kHz wide; the IF bandpass curves easily recovered the ± 5-kHz FM deviation! The trick was to tune to one side of the signal or the other, carefully centering the FM carrier on the center of the tuning skirt, not dead on at the peak! In short: The steeper the slope, the greater the recovered audio for a given deviation.

**Figure 1** illustrates how slope detection works. The curve on the drawing represents a typical, but not exact, representation of how a tuned circuit responds as it is tuned across a carrier. Points A and D denote the bandwidth of the tuned LC circuit. The areas between points A and B and C and D represent the slopes of the tuning curve. Ideally, an AM signal would be tuned so its carrier is at the apex, or center, of the tuning curve. If we center the carrier frequency of the FM transmitter to the same spot, the carrier will swing over both slopes, and any recovered audio would be canceled. Instead, the "sweet spot" is where the FM carrier falls near the midpoint of the slope between A and B, or likewise on the slope of the curve between points C and D. The AM detector output will then swing in correspondence with the aural information carried on the FM carrier.

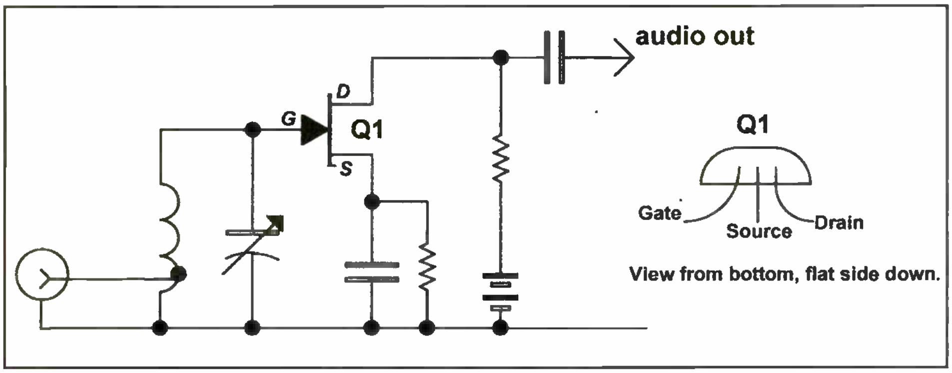


*Figure 3. The infinite-impedance detector offers several advantages over a germanium diode detector. It has gain, doesn't load the tuned circuit, and it features better weak-signal detection.*

Ideally, for maximum audio recovery, the FM deviation will "sweep" over the largest area of one side of the slope as is possible. It's hard to match the tuning curve to the FM deviation, and also any non-linearity in the slope along the rise or fall on the curve (a straight line, like a saw tooth, is ideal) will cause distortion. Too wide a slope and the FM deviation will fall on a very small area on the slope, giving very poor recovered audio. Too much deviation, where the carrier swings beyond the cutoff and into the opposing slope, yields large amounts of distortion on the recovered audio. In practice, these sets do work, but don't expect anything approaching high-fidelity reception!

## The Simplest Receiver

There are several key elements needed for this project to work, most importantly, having a very strong local FM station or two or listen to. Most urban locations are so blessed. You'll also probably need a good outdoor FM or TV antenna to capture enough signal for the set to work, and it's a big plus if your system includes an inline VHF/FM preamplifier.

Let's get started by looking at **Figure 2**, the starting point for our project. It closely resembles the primitive FM crystal set projects shown in those early magazines. The heart of the receiver is the high-quality tuning capacitor and inductor. The tuning capacitor can be salvaged from an old FM tuner or converter, if need be. The tuning capacitor (C1 in the drawings) is a 35-pF capacitor with a built in 3:1 vernier dial reduction, and was salvaged from my junkbox. Any capacitor with a maximum capacity of 25 to 45 pF will work.

The set tunes rather broadly, thus the vernier tuning isn't a necessity, but it is nice to have. One source for the cap is Fair Radio; its 3G-25 variable cap has a vernier drive and three sections with 4-25, 4-20, and 3-17 pF. Two of these sections could be paralleled to yield a larger tuning range. The inductor (L1 in all drawings) is wound from a length of #8 copper ground wire, available from any hardware store. You can substitute a smaller gauge if necessary. The circuit Q could be improved by silver-plating the coil—if you have a means to do so try it. Otherwise, I suggest polishing the copper to a sheen, followed by applying a coat of clear Krylon to prevent tarnishing. The coil consists of six turns; I used a half-inch wood dowel as a form to wind the coil. The antenna tap is made at one-half turn above ground on the coil. **Photo A** shows the tap point and also the tuning capacitor. **Table 1** lists the parts values and sources for all the components used in three versions of the receiver shown in this month's column.

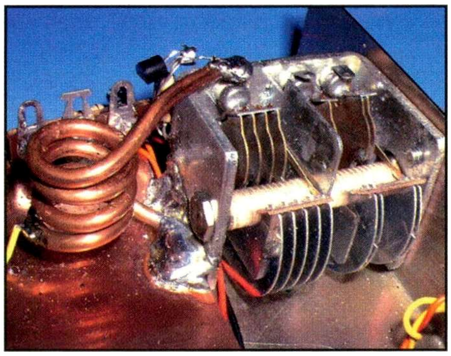

*Photo A. The tuning capacitor and coil form the heart of the crystal set. The Q of these parts determines the tuning slope, and ultimately audio recovery on FM signals. The capacitor should be the best quality available. Often military surplus capacitors with ceramic insulation are available on the surplus market or at hamfests. If you can find one, use it. The tap point for the antenna is visible. Use a short lead between the tap and J1 connector.*

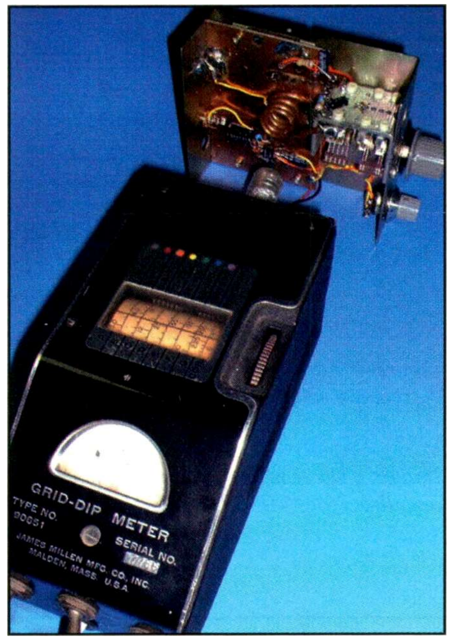


*Photo B. Here's the Millen Grid Dip Meter in action! When tuned to the resonant frequency of the capacitor and coil, the meter on the Millen will dip to a lower value. Fifty or 60 years ago, every ham owned one of these useful pieces of test equipment. That was a time when hams built their own gear. Now using one has become an archaic art.*

I know finding parts can be difficult. I listed a few resources in **Table 1**, including one for a basic kit, sans headphones, for building the basic FM crystal set. This five-dollar postpaid kit can serve as the nucleus for the more advanced versions shown here as well.

## Checking The Tuning Range

A grid-dip meter is the easiest way to check the tuning range of your coil and tuning capacitor combination. A ham friend who is also a builder is a likely candidate to have one of these units in his workshop. **Photo B** shows my venerable James Miller *'dipper* being used to check that my set will tune the entire FM band. These devices are variable oscillators with calibrated tuning ranges. A set of companion plug-in coils allows covering from the broadcast band up through 300 MHz. When the *'dipper's* coil is held near a tuned circuit, and the grid dipper is tuned to that frequency, the grid current in the *'dipper* will drop (or "dip"), as shown on the *'dipper's* built-in meter.

Alternately, a signal generator would also do for checking the tuning range. Compressing or expanding the coil slightly will shift the range: squeezing the coil will allow lower frequency tuning, while

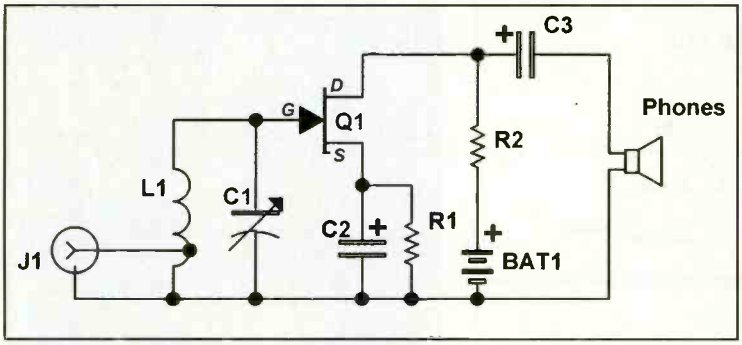


*Figure 4. Adding the infinite-impedance detector to the basic FM crystal receiver might make the difference between hearing a station or not!*

*Photo C. The leads for the infinite-impedance detector should be kept short and direct for VHF. The J-FET leads and associated parts are mounted to the capacitor terminals and frame.* →

### Table 1. Parts List And Recommended Suppliers

| | |
|---|---|
| L1 | #8 copper wire, see text |
| C1 | variable capacitor, 5 to 50 pF max. with knob |
| D1 | 1N34A germanium diode, or equivalent |
| J1 | RCA phono jack or suitable RF connector for antenna |
| C2 | 10 µfd @ 16 volts electrolytic |
| C3 | 10 µfd @ 16 volts electrolytic |
| C4 | 10 µfd @ 16 volts electrolytic |
| C5 | 0.1-mfd ceramic capacitor @ 16 volts |
| C6 | 220 to 470 µfd @ 16 volts electrolytic |
| C7 | 500-pF ceramic disc or silver mica capacitor |
| R1 | 47k-ohm 1/4-watt resistor |
| R2 | 47k-ohm 1/4-watt resistor |
| R3 | 10k-ohm variable potentiometer, audio taper/with knob |
| BAT1 | 9-volt transistor battery with battery clip |
| Phones | 2000-ohm vintage headset or crystal earpiece |
| Speaker | 8-ohm speaker in enclosure |
| Q1 | J-FET, type J-310 |
| U1 | LM-386 DIP package 8-pin audio IC |

**Resources**

• Dan's Small Parts, PO Box 3634, Missoula, MO 59806-3634, (406) 258-2782, www.dansmallpartsandkits.net

This is an excellent resource for all components (ICs, FETs, small parts, and variable caps). Dan's features low prices and is set up to deal with home experimenters. Dan's offers an online catalog and ordering system. Minimum order might apply, check with seller.

• Bill Turner, 1117 Pike Street, St. Charles, MO 63301, (636) 949-2210, www.dialcover.com

Bill offers a kit and copy of the original vintage magazine article for the FM Crystal receiver for $5 postpaid. No frills or headphones, just the basic parts. No minimum order.

• Fair Radio Sales, 2935 St. Johns Road, PO Box 1105, Lima, OH, (419) 227-6573, www.fairradio.com

Surplus stalwart Fair Radio has a nice three-section variable (catalog #3G-25) that will work well. Price is $6. They also offer some high-Q ceramic military versions, but these are more expensive. Minimum orders might apply, check with seller.

expanding the coil will increase the higher end of the tuning range. A 40-pF variable capacitor should tune from 80 MHz through at least 130 MHz into the aircraft band. At worst, you may have to wind a new coil with a turn added or removed before you're able to tune the desired range. Adding a full or partial turn will lower the frequency. **Photo B** shows my Millen dip meter in action.

## Improving The Detector

Crystal diodes make poor detectors. Germanium diode detectors don't work well on weak signals; for a weak enough signal they act more like resistors than diodes. **Figure 3** shows a circuit for a neat device called an Infinite Impedance Detector. This detector offers some gain and doesn't load the tuned circuit as much as a diode detector would; hence the Q and selectivity are also improved. The J-FET gate adds some capacity to the tuned circuit, and this can reduce the high-frequency tuning by several MHz.

**Photo C** shows how the J-FET and associated parts for the infinite-impedance detector are mounted using short leads. The gate is tied directly to the tuning capacitor stator terminal, and the FET's *source* lead bypass caps and biasing resistor are tied directly to the capacitor frame for good VHF performance.

**Figure** 4 shows how the infinite-impedance detector is incorporated in the FM crystal receiver. Parts values are given in **Table 1**. The detector will drive a pair of vintage high-impedance headphones (2000 ohms or better) directly. I use a pair of military sound-powered headphones with a matching transformer. Adding the

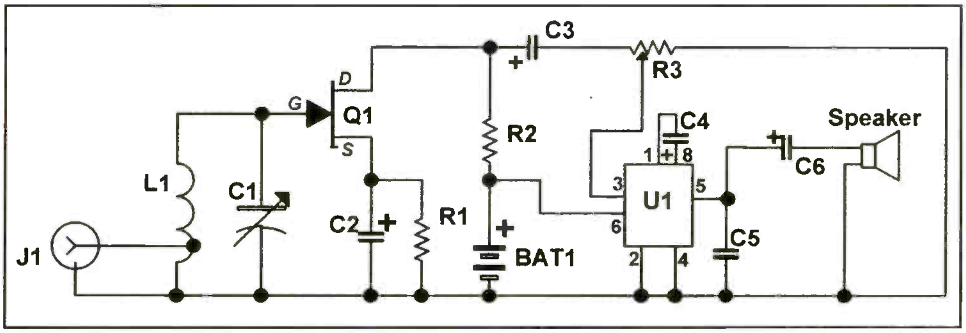


*Figure 5. Adding the high-gain audio stage gives loudspeaker volume on strong stations.*

*Photo D. The audio amp IC is mounted using "dead bug" construction techniques. The larger parts are glued to the pc board to alleviate stress on the IC leads.*

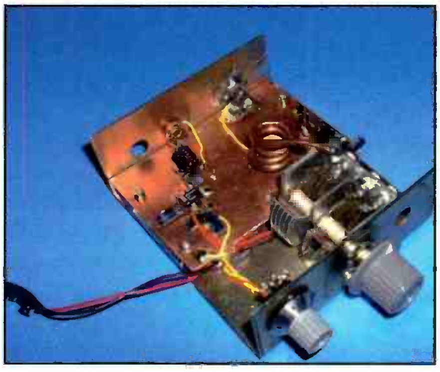

*Photo E. Here's a top view of the completed receiver. Ugly, but it works—and it was intended as an experimental prototype to begin with.*

infinite-impedance detector allowed me to hear some FM stations from my rural home when using some high-gain tower-mounted VHF antennas.

You might want to try this detector on your AM BCB crystal sets; it makes a big improvement!

## Adding An Audio Amplifier

**Figure 5** shows the final phase of the FM crystal receiver. A small 8-pin LM-386 audio IC gives enough gain for loudspeaker level volume, or to drive more contemporary low-impedance headphones. I mounted the IC and supporting parts "dead bug" fashion on the pc board. If you're not familiar with this breadboarding technique, the parts are soldered directly to the copper side of an unetched pc board for ground, and are self-supporting or glued in place as needed. (ICs were sometimes mounted on their backs, looking like little dead bugs; hence the name.)

It's not very pretty, as shown in **Photo D**, but it works and is good for quickly prototyping circuits on the fly. I think some builders call this technique *Ugly Board* construction. Hot glue assisted in mounting and supporting the IC and larger components to the board. **Photo E** shows an overall view of the entire receiver. Again, it isn't pretty, since I considered this to be an experimental project. An off/on switch is needed to preserve battery life.

*Photo F. This is my 6S321 Stars-and-Bars Zenith! Sorry for the mix up! As you can see, this cabinet needs a bit of work. I'd started scraping the old lacquer off the top when the photo was taken. Chemical strippers risk damaging the photo-etched lacquered patterns on the front, which I intend to restore and save.*

## An Apology

Our opening photograph in the July 2004 issue purportedly showed the deplorable condition of my Zenith 6S321 cabinet. What accidentally got forwarded for publication was a photo of a nicely restored example from the webpages of Mike Urban's Internet site at www.urban-antiqueradio.com. I had saved his photo as an example to follow when restoring my Zenith. Hopefully **Photo F** is the correct photo. Anyway, visit Mike's website to see some nicely restored radios in his collection, and to check out a few he's offering for sale.

Well, that's it for this month. If you build one of these sets, I'd like to hear about it, and photos would be great! Let me hear about your other projects, as well. Until next month, keep those soldering irons warm and those letters coming in! ■